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Sustainability assessment of functionally enhanced polymers – engineered nanomaterials or conventional additives? (Platform presentation)

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For many years the environment has produced, and been exposed to, natural occurring nanomaterials being it through e.g. dust, viruses or volcanic ash. Additionally, nowadays engineered nanomaterials (ENMs) are increasingly manufactured and used in consumer products. Due to this development, questions regarding the sustainability and safety of ENMs are raised and it is often asked whether, in a life cycle perspective, ENMs are more sustainable than the conventional alternatives. The aim of the MINANO project was to mass produce Ag, ZnO and $Mg(OH)_2$ ENMs that can be incorporated into PP, PVC-wood and PS polymers so these can improve the antimicrobial/antifungal, UV-protection or flame retardant properties. To include the whole life cycle, for comparison of environmental impacts of different polymer products, the holistic impact assessment methodology of life cycle assessment (LCA) was used. By doing so, the study accounts for potential environmental impacts generated throughout the entire life cycle (from extraction of raw materials to the final disposal of the product) of the functionally enhanced polymer products, either produced with the MINANO technology or the currently conventional approach.

LCA is a holistic, 14040 series ISO standardised, tool to assess the potential impacts of a product or a system throughout their entire life cycle [1]. Impact categories assessed include local (e.g. ecotoxicity), regional (e.g. acidification) and global (e.g. climate change, resource use) impacts. The impact potentials are considered through the entire product life cycle in order to assess the overall environmental impact potentials and to avoid burden shifting of impacts [2]. The applied LCIA method was IMPACT2002+ [3].

The LCA results show that the production of nano-based polymers leads to higher environmental impacts, due to higher energy and resource demand for production of the ENMs, than the conventional additive-based polymers. Several LCA studies have reported similar conclusions [4] [5] [6], however in most studies so far the potentially improved functionality of ENMs-products have not been taken into account. In this study nano-based polymers have a higher value when in use due to the enhanced antimicrobial/antifungal (Ag/ZnO), UV-protection (ZnO), flame retardant ($Mg(OH)_2$) product functionality. This means that the improved use-phase of the nano-enhanced polymers could outweigh the conventional additive-based polymers, depending on the actual application of the products. Evaluation of the use phase can be limited by other factors than just the material durability. The potential environmental impacts of use and disposal of nano-based materials are not scientifically fully understood at this time [7], due to the poorly understood fate and effect of ENMs in water, air and soil. Additionally, the release of ENMs depends on the polymer matrix in which ENMs are embedded, while the geographically differentiated end-of-life patterns can influence the potential release of ENMs to the environment. However, in this project the laboratory testing, simulating use-phase scenarios for the MINANO polymers, showed no significant release of ENMs to the ambient.

Based on this study it can be concluded that ENM enhanced polymers can in terms of environmental impact outperform the conventional based polymers with antimicrobial/antifungal, UV-protection and flame retardant functionalities, but this highly depends on the actual achieved product improvement/added value in the use-phase.

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